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Analysis of the Trade-Off of Exploration Between Onshore and Offshore Regions Volume II: Appendices

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ICF INCORPORATED
1828 L STREET, NORTHWEST, SUITE 709
WASHINGTON, D.C. 20036

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ANALYSIS OF THE TRADE-OFF OF EXPLORATION BETWEEN ONSHORE AND OFFSHORE REGIONS AND POTENTIAL ENVIRONMENTAL HAZARDS AND SAFEGUARDS

VOLUME II: APPENDICES

Submitted to the Office of Planning and Evaluation,
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CONTENTS

		Page
Volume I: Report		
I	Summary	1
II	Analysis of Oil and Natural Gas Reserves in Onshore and Offshore Regions	22
III	The Effects of Government Policies, Economic Conditions and Cost Factors on the Exploration Decision	50
IV	The Trade-Off of Exploratory Activity on the Margin Among Competing Onshore and Offshore Regions	85
V	Environmental Hazards and Safeguards	118
Volume II: Appendices		
Appendix 1:	A Background Discussion on Reserve Estimates	1
Appendix 2:	Regional Rankings	10
Appendix 3:	Composition of Onshore Regions	35
Appendix 4:	Definitions	36
Appendix 5:	Types of Exploratory Drilling	40
Appendix 6:	Derivation of the Mathematical Model Used to Simulate the Offshore/Onshore Exploration Decision	41
Appendix 7:	References	47

APPENDIX 1:

A BACKGROUND DISCUSSION ON RESERVE ESTIMATES

APPENDIX 1

A BACKGROUND DISCUSSION ON RESERVE ESTIMATES

To understand how the categories used to describe oil and gas reserves differ, it is useful to think of the entire supply of these resources remaining in natural reservoirs as the total current inventory. At any point in time, the total current inventory is classified according to the likelihood of future discovery and production of reserves. As new information on the likelihood of discovery and production becomes available, the reserve estimates in each category may be changed by:

- shifting estimated reserves between categories; and
- reducing the total current inventory by production of some reserves and increasing or decreasing the total current inventory by reevaluation of the volume of reserves remaining to be discovered.

Information resulting in reappraisal of the volume of reserves (barrels of oil or cubic feet of natural gas) assigned to any category may be based on:

- New knowledge about the volume of favorable geological formations, e.g. those which have resulted in successful oil and gas exploration in the past in areas where no previous drilling has occurred,
- Results of new exploratory drilling in both productive fields and new fields,
- Changing technology for exploration and development, and
- Changing economic conditions which may permit the profitable exploration and development of fields previously classified non-commercial.

Reserve categories for oil and natural gas are generally similar in concept. However, some differences in terminology exist because reserve estimates for each are compiled by different organizations. We will discuss the reserve estimates for oil in detail and subsequently focus on those areas in which natural gas reserves are defined differently.

The chart on the following page illustrates, in greatly simplified fashion, the categories in which the total current inventory of oil is classified. While differences in terminology exist, reserve estimates generally fall into one of three categories.

- Non-Discoverable Reserves -- oil in unknown reservoirs which is believed to be too difficult or costly to discover.
- Discoverable Reserves -- oil in unknown reservoirs which is believed to be discoverable under reasonable assumptions about technological improvements and prices.
- Discovered Reserves -- oil in known reservoirs. Discovered reserves are further broken down by likelihood of production.

The arrows on Chart 1 show how the reserve estimates may be shifted between categories. The dotted lines indicate that the entire "pie" may be increased or reduced by reevaluating the reserves in unknown reservoirs. The only estimates which are based on specific information on known reservoirs are discovered reserves and these will increase as discoverable reserves are discovered and decrease as some reserves are produced.

Estimates of discoverable and non-discoverable reserves in unknown reservoirs have been developed in special studies by the U. S. Department of Interior and other organizations. Because they are based on limited information on the geology of unexplored areas, these estimates vary greatly. A recent National Petroleum Council (NPC) estimate of remaining discoverable oil reserves is 385 billion barrels.

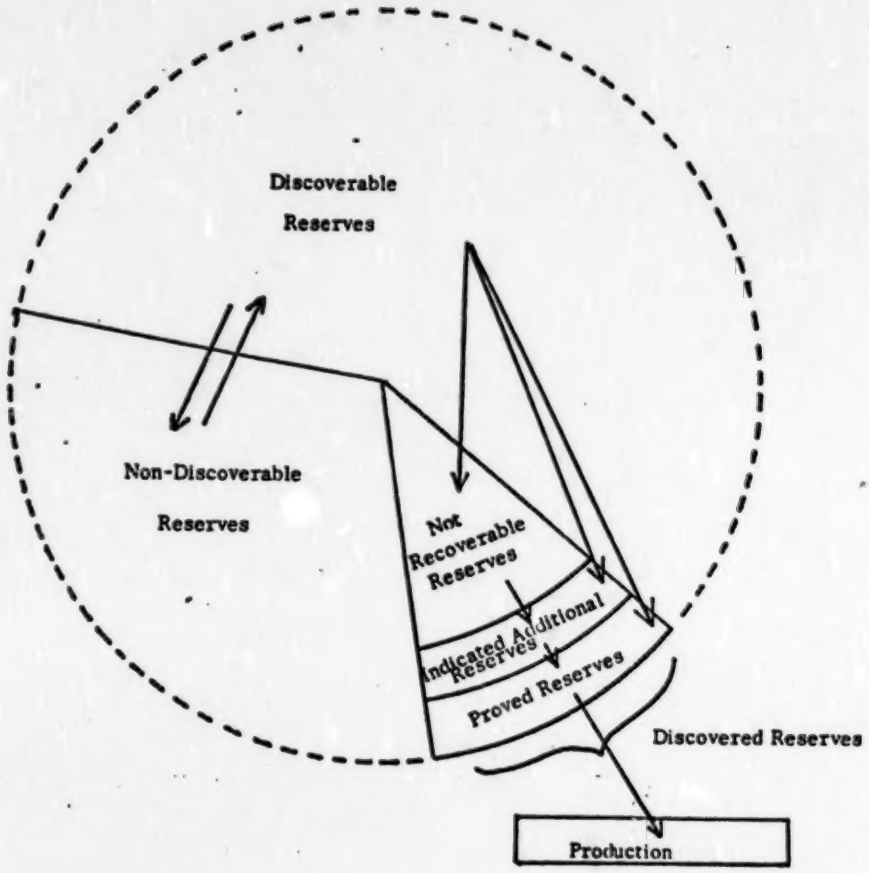
The petroleum industry compiles statistics only for discovered reserves. Data are reevaluated and published annually by the American Petroleum Institute (API). The API publishes estimates of two categories of discovered reserves:

1. Proved Reserves: The current estimated quantity of crude oil which geological and engineering data demonstrate with reasonable certainty to be recoverable from known reservoirs under existing economic and operating conditions;

2. Indicated Additional Reserves: Quantities of crude oil in existing fields which are expected to be economically recoverable with improved recovery techniques. (Indicated Additional Reserves are not included in the category of Proved Reserves.)

CHART 1

CLASSIFICATIONS OF THE TOTAL CURRENT INVENTORY OF OIL



These reserve estimates all are subject to reclassification based on new information. The results of new drilling or changes in technology and economic conditions may lead to a reclassification of a portion of indicated additional reserves to proved reserves. The estimate of proved reserves may be increased or decreased based on new information on the known reservoir. Finally, that portion of proved reserves which is lifted is reclassified as production.

The preceding paragraphs discussed how reserves are estimated at any point in time. Industry statistics also measure ultimate recovery and cumulative production. Chart 2 shows how these measures are related to the total original oil inventory.

The API defines Ultimate Recovery as "the quantity of crude oil which has been produced and is expected to be produced from known reservoirs under current economic and operating conditions." It equals the sume of cumulative production and current estimates of proved reserves. Original Oil-in-Place is defined by the API as "the amount of crude oil in known reservoirs prior to any production". It equals the sum of:

- ultimate recovery,
- indicated additional, and
- non-commercial reserves.

To relate Original Oil-in-Place to the total original oil inventory, it is necessary to add to this amount estimates of the discoverable current inventory from unknown reservoirs and the non-commercial inventory from unknown reservoirs. The sum of these three amounts equals the total original oil inventory.

The primary differences in the categories used to define natural gas are for estimates of discoverable reserves. An industry sponsored committee, the Potential Gas Committee, makes biannual estimates of the potential supply of natural gas remaining to be discovered. The PGC defines the potential supply of natural gas as "the prospective quantity of natural gas yet to be found and proved by all wells which may be drilled in the future under assumed conditions of adequate but reasonable prices and normal improvements in technology." Non-discoverable deposits are not reported as potential supply. The PGC estimate is some (unknown) proportion of the total current inventory. The potential supply is reappraised biannually, based on new knowledge of geological formations, changing operating and economic conditions, and results of new exploratory drilling. It was estimated to be 1146 trillion cubic feet as of December 31, 1972. Chart 3 shows how potential supply relates to other reserve estimates.

The estimate of the potential supply of natural gas is divided into three categories:

1. Probable -- The most assured of new supplies results from the growth of existing fields. For example, a producing field of 40,000 acres may have an additional 20,000 acres which is highly prospective. The 20,000 acres of unproved supply would be categorized as probable.

2. Possible -- Less assured is the supply from new field discoveries in formations previously productive; such new fields would be distinctly separated from existing fields. For example, an undrilled structure would be in this category.

3. Speculative -- The least likely of new supplies is attributable to new field discoveries in formations or provinces not previously productive, such as the Atlantic Coast.

Each reappraisal may result in shifting of estimates categories or a revision upward or downward.

The results of exploratory drilling may lead to a reclassification of some portion of potential supply to Proved Reserves. The American Gas Association (AGA) publishes annual estimates of Proved Reserves based on data supplied by the industry on known reservoirs. The definition of proved reserves is similar to that used by the API, but gas in underground storage also is included. The AGA does not measure Indicated Additional Reserves. Revisions may be made to Proved Reserve estimates based on the results of further drilling. As proved natural gas reserves are lifted, this amount is withdrawn from the current inventory and reclassified as production.

As shown in Chart 4, definitions of Ultimate Recovery and Cumulative Production also are similar for oil and natural gas. The PGC defines Ultimate Discoverable Volume as the "volume of gas expected to be produced during the entire life of the industry". It is the sum of:

- Cumulative Production,
- Proved Reserves, and
- Potential Supply.

CHART 2

ORIGINAL OIL-IN-PLACE AND ULTIMATE RECOVERY OF OIL

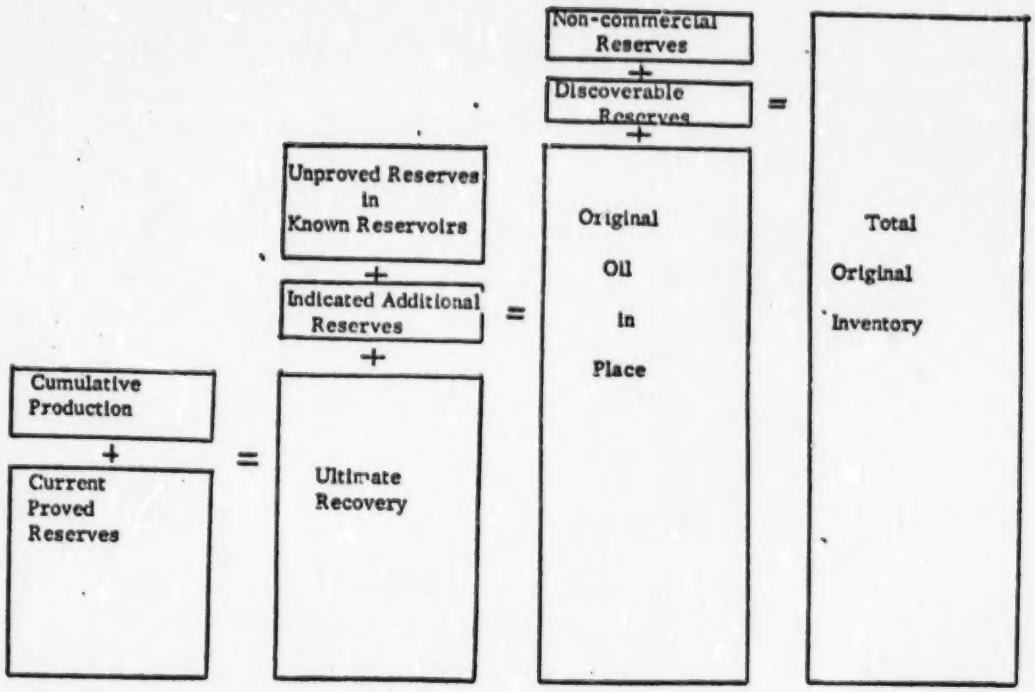


CHART 3

CLASSIFICATIONS OF THE TOTAL CURRENT INVENTORY OF NATURAL GAS

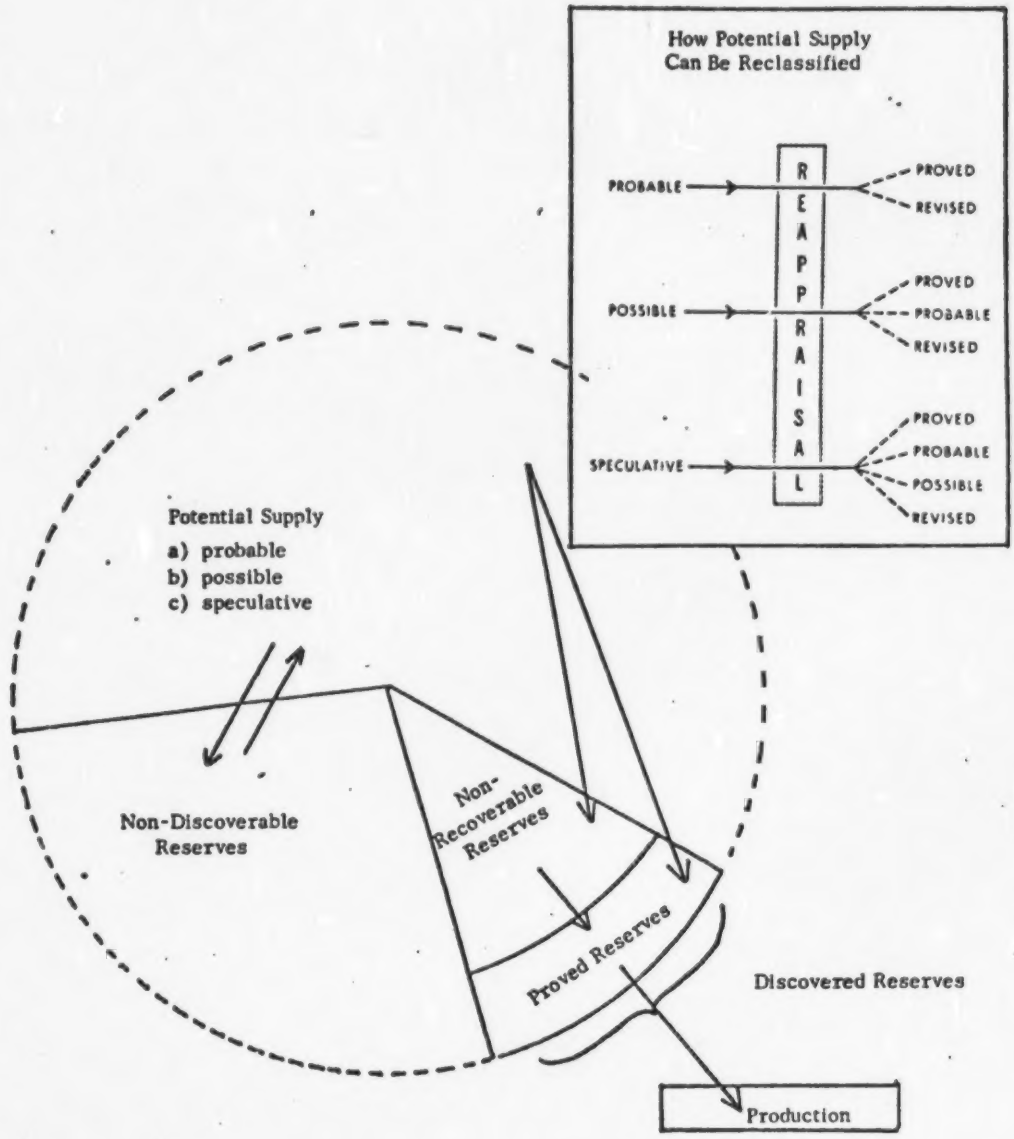
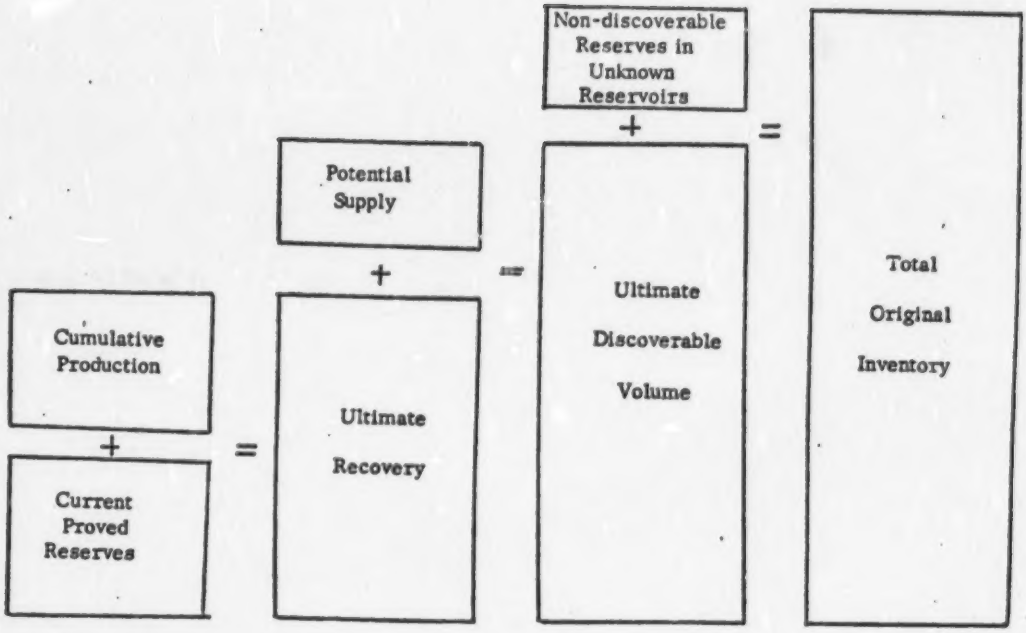


CHART 4

ULTIMATE RECOVERY AND DISCOVERY OF NATURAL GAS



This differs from the API definition of Original Oil in Place which includes information on known reservoirs only. Ultimate Discoverable Volume is an unknown fraction of the total original oil inventory. The other component, which is not estimated, is the discoverable inventory from unknown reservoirs.

These categories of reserve estimates are referred to throughout the report. More detailed definitions of these concepts and other terms can be found in Appendix 4.

APPENDIX 2:

REGIONAL RANKINGS

TABLE 1

1. PROVED RESERVES OF CRUDE OIL
(As of December 31, 1972)

Ranking	Reserves (Billions of Barrels)
1. Southwest	12
2. Alaska	10
3. West	5
4. S. Louisiana & S. Texas	5
5. Gulf of Mexico	3
6. Pacific Coast	1
7. Southeast	.6
8. East	.5
9. Atlantic Coast	0
10. Florida Coast	0

Sources: Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972. op.cit. pp. 22-23.
Energy in California. op.cit. p. 22.

TABLE 2

2. REMAINING DISCOVERABLE OIL IN PLACE
(As of December 31, 1972)

Ranking	Volume (Billions of Barrels)
1. Alaska	119
2. West	88.2
3. Pacific Coast	48
4. Southwest	45'
5. S. Louisiana and S. Texas	29
6. Gulf of Mexico	27
7. Atlantic Coast	14
8. East	10

Source: U.S. Energy Outlook. National Petroleum Council. December, 1972, p. 72.

NOTE: NPC regions are different from the regions developed for this analysis. Thus this ranking is not exactly comparable to the others presented. It is included because the NPC provides the only estimate of potential supply for oil. The major discrepancy is that no estimate for the Southeastern U.S. is available. Reserves for the offshore portion are included in either the Atlantic or Gulf estimates, thus inflating those figures. Reserves for onshore portion are included in the estimates for the Eastern U.S. and S. Louisiana and S. Texas.

TABLE 3

3. ULTIMATE RECOVERY OF CRUDE OIL AS A PERCENT OF ORIGINAL-OIL-IN-PLACE, 1972

Ranking	Percent
1. S. Louisiana and S. Texas	47%
2. Gulf Coast	46
3. Alaska	39
4. Southeast	33
5. Southwest	30
6. West	26
7. East	25
8. Pacific Coast	13

Source: Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972. op.cit., p. 72.

TABLE 4

4. CUMULATIVE PRODUCTION OF OIL AS A PERCENT OF ULTIMATE RECOVERY, 1972

Ranking	Percent
1. Alaska	5%
2. Gulf Coast	50
3. Southeast	75
4. S. Louisiana and S. Texas	78
5. Southwest	79
6. West	79
7. East	88

Source: Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972. op.cit., p. 72.

TABLE 5

5. RESERVE/PRODUCTION RATIO, 1972

Ranking	Percent
1. Alaska	144.3
2. Southwest	9.8
3. East	7.6
4. S. Louisiana and S. Texas	7.2
5. Gulf of Mexico	6.4
6. West	5,5
7. Southeast	4.2

Source: Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972. op. cit. p. 72.

TABLE 6

1. PROVED RESERVES OF NATURAL GAS
(As of December 31, 1972)

Ranking	Volume (Trillions of Cubic Feet)
1. S. Louisiana and S. Texas	89
2. Southwest	75
3. Gulf Coast	39
4. Alaska	32
5. West	21
6. East	8
7. Southeast	2
8. Pacific Coast	1
9. Atlantic Coast	0
10. Florida Coast	0

Source: Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972. op. cit. p. 114.

TABLE 7

2. FUTURE POTENTIAL SUPPLY OF NATURAL GAS
(As of December 31, 1972)

Ranking	Volume (Trillions of Cubic Feet)
1. Alaska	366
2. Southwest	235
3. Gulf of Mexico	148
4. S. Louisiana and S. Texas	117
5. West	98
6. East	76
7. Florida Coast	36
8. Atlantic Coast	35
9. Southeast	24
10. Pacific	11

Source: Potential Gas Committee. (Press Release) op. cit.

TABLE 8

3. FUTURE POTENTIAL SUPPLY OF NATURAL GAS:
PROBABLE SUPPLY ONLY
(As of December 31, 1972)

Ranking	Volume (Trillions of cubic feet)
1. Gulf of Mexico	57
2. S. Louisiana and S. Texas	57
3. Alaska	54
4. Southwest	46
5. East	26
6. West	23
7. Southeast	2
8. Pacific Coast	1
9. Atlantic Coast	0
10. Florida Coast	0

Source: Potential Gas Committee. (Press Release) op. cit.

TABLE 9

6. FUTURE POTENTIAL SUPPLY OF NATURAL GAS LESS THAN 600 FT DEEP OFFSHORE AND LESS THAN 15,000 FT DEEP ONSHORE

Ranking	Volume (Trillions of Cubic Feet)
1. Southwest	161
2. Alaska	148*
3. Gulf of Mexico	133
4. West	91
5. S. Louisiana and S. Texas	79
6. East	71
7. Florida Coast	33
8. Atlantic Coast	30
9. Southeast	11
10. Pacific Coast	7

* The estimate for Alaska was not broken out by depth; instead, we used the potential supply listed as possible and probable.

Source: Potential Gas Committee. op. cit.

TABLE 10

4. CUMULATIVE PRODUCTION OF NATURAL GAS AS A PERCENT OF ULTIMATE RECOVERY, 1972

Ranking	Percent
1. Alaska	3%
2. Gulf of Mexico	38
3. S. Louisiana and S. Texas	60
4. Southeast	67
5. West	68
6. Southwest	72
7. East	79

Source: Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canado and United States Productive Capacity as of December 31, 1972, op. cit., pp. 114, 196-218.

TABLE 11

5. ULTIMATE RECOVERY AS A PERCENT OF ULTIMATELY DISCOVERABLE VOLUME, 1972

Ranking	Percent
1. Alaska	8%
2. Pacific Coast	8
3. Southeast	20
4. Gulf of Mexico	30
5. East	34
6. West	41
7. Southwest	53
8. S. Louisiana and S. Texas	66

Sources: Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in United States and Canada and United States Productive Capacity as of December 31, 1972. op.cit., pp. 114, 196-218. Potential Gas Committee. op.cit.

TABLE 12

7. RESERVE/PRODUCTION RATIO FOR NATURAL GAS, 1972

Ranking	R/P Ratio
1. Alaska	214.4
2. Gulf of Mexico	21.0
3. East	17.2
4. West	13.5
5. Southeast	11.9
6. Southwest	9.2
7. S. Louisiana and S. Texas	8.9

Source: Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972. op. cit., p. 114.

TABLE 13

COST PER FOOT OF TOTAL SUCCESSFUL OIL WELLS, 1971

Ranking	Cost
1. East	$11.33
2. West	11.68
3. Southwest	12.97
4. S. Louisiana and S. Texas	18.40
5. Southeast	23.15
6. Gulf of Mexico	55.59
7. Pacific Coast	60.10
8. Alaska	117.42

Source: Joint Association Survey. American Petroleum Institute, Independent Petroleum Association of America, and Mid-Continent Oil and Gas Association. November, 1972. pp. 6 and 7.

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TABLE 14

COST PER FOOT OF TOTAL SUCCESSFUL GAS WELLS, 1971

Ranking	Cost
1. East	$14.28
2. West	16.59
3. Southwest	27.38
4. S. Louisiana and S. Texas	28.90
5. Gulf of Mexico	69.56
6. Southeast	83.18
7. Alaska	132.47

Source: Joint Association Survey. op. cit., pp. 6-7.

TABLE 15

AVERAGE DRILLING COST PER BARREL OF NEW PROVED OIL RESERVES, 1971

Ranking	Cost per Barrel
1. Southwest	$ .23
2. Southeast	.26
3. S. Louisiana and S. Texas	.49
4. West	.53
5. East	.61
6. Gulf of Mexico	.69
7. Alaska	.78

Source: Joint Association Survey, op. cit., p. 6-7. Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1971. American Gas Association, American Petroleum Institute and Canadian Petroleum Association, 1972, pp. 22-23.

NOTE: Drilling costs are for successful wells only.

TABLE 16

AVERAGE DRILLING COST PER MILLION CUBIC FEET OF NEW PROVED NATURAL GAS RESERVES, 1971

Ranking	Cost
1. Alaska	$ .005
2. East	.015
3. West	.035
4. Southwest	.055
5. Gulf of Mexico	.063
6. S. Louisiana and S. Texas	.075

Source: Joint Association Survey. op. cit., pp. 6-7.

NOTE: No estimate for Region 2 is shown because new reserve additions were negative. Drilling costs are for successful wells only.

TABLE 17

AVERAGE DEPTH OF TOTAL SUCCESSFUL OIL WELLS, 1972

Ranking	Average Depth (feet)
1. East	2435
2. Southwest	4237
3. West	4587
4. S. Louisiana and S. Texas	5839
5. Gulf of Mexico	10591
6. Alaska	11042
7. Southeast	11838

Source: World Oil. July, 1973. p. 73.

TABLE 18

AVERAGE DEPTH OF TOTAL SUCCESSFUL GAS WELLS, 1972

Ranking	Average Depth (Feet)
1. East	3740
2. West	5114
3. Southwest	5496
4. Alaska	7286
5. S. Louisiana and S. Texas	8704
6. Southeast	10610
7. Gulf of Mexico	10904

Source: World Oil. op.cit., p. 73.

TABLE 19

PROVED RESERVES ADDED PER FOOT OF TOTAL SUCCESSFUL OIL WELLS, 1972

Ranking	Reserves (Barrels of 42 U.S. Gallons)
1. Gulf of Mexico	64
2. West	49
3. Alaska	48
4. Southeast	29
5. Southwest	24
6. S. Louisiana and S. Texas	21
7. East	3

NOTE: The estimate of proved reserves is based on net revisions, extensions, and new discoveries only. Annual production has not been subtracted.

Source: World Oil. op. cit., p. 73
Proved Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972. op.cit. pp. 22-23.

TABLE 20

PROVED RESERVES ADDED PER FOOT OF TOTAL SUCCESSFUL GAS WELLS, 1972

Ranking	Reserves (millions of cubic feet)
1. Gulf of Mexico	11.5
2. Alaska	10.8
3. Southwest	4.1
4. Southeast	2.9
5. West	2.7
6. S. Louisiana and S. Texas	2.4
7. East	2.1

NOTE: The estimate of proved reserves is based on net revisions, extensions, and new discoveries only. Annual production has not been subtracted.

Source: World Oil. op. cit. p. 73
Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1972. op. cit. p. 114.

TABLE 21

AVERAGE DEPTH OF SUCCESSFUL EXPLORATORY WELLS
WHICH FOUND OIL, 1971

Ranking	Average Depth (Feet)
1. East	2535
2. Southwest	5216
3. West	6926
4. Pacific Coast	7242
5. S. Louisiana and S. Texas	8710
6. Alaska	10290
7. Southeast	10626
8. Gulf of Mexico	12278

Source: American Association of Petroleum Geologists Bulletin. Vol. 56. No. 7. July 1972, p. 1163.

TABLE 22

AVERAGE DEPTH OF SUCCESSFUL EXPLORATORY WELLS
WHICH FOUND GAS, 1972

Ranking	Average Depth (Feet)
1. East	3178
2. West	5593
3. Southwest	7878
4. S. Louisiana and S. Texas	9387
5. Southeast	12385
6. Gulf of Mexico	12464

Source: American Association of Petroleum Geologists Bulletin. op. cit.

TABLE 23

PERCENTAGE OF SUCCESSFUL EXPLORATORY WELLS, 1971

Ranking	Percent
1. Alaska	20%
2. East	20
3. Southwest	19
4. S. Louisiana and S. Texas	19
5. Gulf of Mexico	15
6. West	10
7. Southeast	8
8. Pacific Coast	5

Source: American Association of Petroleum Geologists Bulletin. op. cit.

TABLE 24

PERCENTAGE OF SUCCESSFUL NEW FIELD WILDCATS, 1971

Ranking	Percent
1. Gulf of Mexico	13%
2. Southeast	12
3. S. Louisiana and S. Texas	11
4. Southwest	11
5. East	10
6. West	7
7. Pacific Coast	0
8. Alaska	0

Source: American Association of Petroleum Geologists Bulletin. op. cit.

TABLE 25

PERCENTAGE OF SUCCESSFUL NEW POOL WILDCATS, 1971

Ranking	Percent
1. S. Louisiana and S. Texas	38%
2. East	26
3. West	17
4. Southwest	16
5. Gulf	9
6. Southeast	0
7. Pacific Coast	0

Source: American Association of Petroleum Geologists Bulletin. op. cit.

APPENDIX 3:

COMPOSITION OF ONSHORE REGIONS

APPENDIX 3

The five lower 48 onshore regions are composed of the following Potential Gas Committee areas:

1. Region 1 -- Eastern United States, composed on PGC Area A -- Ohio, Kentucky, Tennessee, Georgia, N. Carolina, S. Carolina, Virginia, W. Virginia, Maryland, Delaware, Pennsylvania, New Jersey, New York, Rhode Island, Massachusetts, Vermont, New Hampshire, Maine and PGC Area C -- Minnesota, Wisconsin, Michigan, Iowa, Illinois, Indiana, Missouri.

2. Region 2 -- Southeastern United States, composed of PGC Area B -- Mississippi, Alabama, Florida

3. Region 3 -- Southwestern United States, composed of: PGC Area D -- N. Louisiana, Arkansas, and Central Texas (RR comm. Dists. 5, 6, 7B and 9); PGC Area J - North -- Kansas, Oklahoma and Texas RR Comm. Dists. 7C, 8 and 8a.

4. Region 4 -- South Louisiana and South Texas, composed of PGC Area E and PGC Area G -- Texas RR Comm Dists. 1, 2, 3 and 4.

5. Region 5 -- Western United States, composed of: PGC Area H, Rocky Mountains -- N. Dakota, S. Dakota, Nebraska, Montana, Wyoming, Colorado, Utah; PGC Area I, Southern Rocky Mountains -- Arizona and New Mexico; and, PGC Area L -- California, Nevada, Oregon, Washington.

APPENDIX 4:

DEFINITIONS

DEFINITIONS

Proved Reserves (API/AGA definition)

The current estimated quantity of crude oil (natural gas, natural gas liquids) which geological and engineering data demonstrate with reasonable certaining to be recoverable from known reservoirs under existing economic and operating conditions. The AGA estimates include natural gas in underground storage.

Indicated Additional Reserves (API definition)

Quantities of crude oil in existing fields which are expected to be economically recoverable with improved recovery techniques. Indicated Additional Reserves are not included in the category of Proved Reserves.

Potential Reserves (PGC definition)

The prospective quantity of natural gas yet to be found and proved at any given data by all wells which may be drilled in the future under assumed conditions of adequate but reasonable prices and normal improvements in technology. Potential supply is a volume which exists in addition to proved reserves. It is divided into three categories:

Probable - Most likely, results from the expansion of existing fields.

Possible - Less likely, results from new field discoveries in formations previously productive.

Speculative - Least likely, attributable to new field discoveries in formations not previously productive.

Original Oil-Place (API definition)

Estimated amount of oil/gas in known reservoirs prior to any production. Known reservoirs include those that are: (1) currently productive; (2) estimated to have proved reserves but from which there has been no production; and (3) depleted.

Ultimate Recovery (API/AGA definition)

Quantity of crude oil/natural gas which has been produced and is expected to be produced in the future if there are no substantial changes in present economic conditions and known production technology. The current estimate of ultimate recovery thus is the sum of: (1) cumulative production; and (2) current estimated proved reserves.

Ultimately Discoverable Volume (AGA definition)

The volume of gas (or oil) expected to be produced during the entire life of the industry. It includes cumulative production, proved reserves, and potential supply.

Crude Oil (API definition)

Volumes Reported as crude oil include:

(1) Crude oil -- a mixture of hydrocarbons that exists in the liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities.

(2) Condensates -- hydrocarbons that exist in the gaseous phase in natural imderground reservoirs but are liquid at atmospheric pressure.

(3) Small amounts of non-hydrocarbons produced with the oil.

Natural Gas (AGA definition)

Volumes reported as natural gas are a mixture of hydrocarbon compounds and small quantities of various non-hydrocarbons existing in the gaseous phase or in solution with oil in natural underground reservoirs. Natural gas is classified by the AGA in two categories:

(1) Non-associated -- free natural gas not in contact with crude oil in the reservoir.

(2) Associated-Dissolved - combined volume of natural gas which occurs in crude reservoirs either as free gas (associated) or as gas in a solution with the crude oil (dissolved.)

Non-commercial Reservoirs

Oil or gas reservoirs which are too costly to explore and develop under current operating and economic conditions.

Net Production (API/AGA definition)

Volume of crude oil (natural gas, natural gas liquids) which is produced from reservoirs during a given period of time.

Cumulative Production (API/AGA definition)

Sum of estimated production for the current year and actual production of each prior year.

Reserve/Production (R/P) Ratio

Proved reserves (year end) divided by net production. Shows the number of years current proved reserves will be adequate to meet current production levels.

Reserve Additions (API/AGA definition)

Changes in reserves during the year. Includes revisions, extensions, new field discoveries, new reservoir discoveries in oil fields, and net change in underground storage for natural gas and NGL.

Revisions to Reserves - (APJ/AGA definition)

Changes in earlier estimates of proved reserves upward or downward based on new information obtained from additional drilling and production history.

Extensions to Reserves - (APJ/AGA definition)

Additions to proved reserves resulting from enlargement of the proved area of previously discovered reservoirs.

Outer Continental Shelf

Submerged lands lying seaward of a distance of three miles from the coast line which are under the jurisdiction of the Federal government. (Only Florida and Texad have jurisdiction over the seabed more than three miles from their coastlines.)

Developmental Well (AAPG definition)

A well drilled with the purpose of exploiting accumulation discovered by previous drilling.

Exploratory Well (AAPG definition)

A well drilled with the purpose of discovering new pools. Exploratory wells include five types of wells:

1. outpost or extension

2. shallower pool

3. deeper pool

4. new pool wildcat

5. new field wildcat.

New Pool Wildcat (AAPG definition)

A well drilled outside the limits of a proven pool but on a structure/environment already productive.

New Field Wildcat (AAPG definition)

A well drilled in a new field never before productive.

APPENDIX 5:

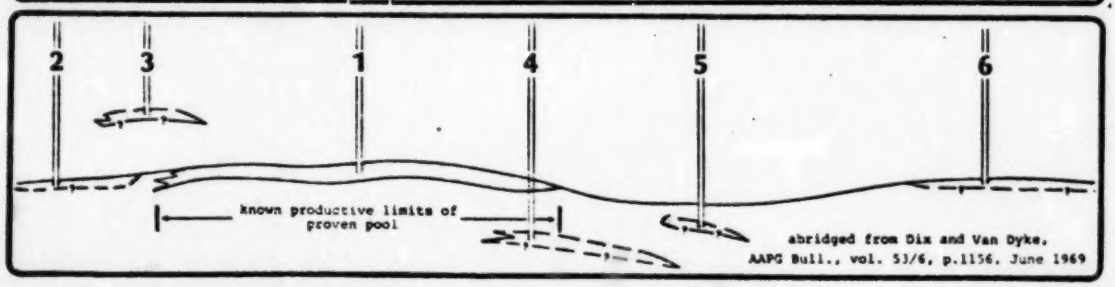
TYPES OF EXPLORATORY DRILLING

TYPES OF EXPLORATORY DRILLING

The chart below illustrates the objectives of each type of well and what the outcome must be for any well to be classified successful.

CLASSIFICATION OF WELLS

DRILLING OBJECTIVE			ILLUSTR	INITIAL WELL CLASSIFICATION	FINAL WELL CLASSIFICATION	
					SUCCESSFUL	UNSUCCESSFUL
EXPLOITATION OF ACCUMULATION DISCOVERED BY PREVIOUS DRILLING			1	DEVELOPMENT	DEVELOPMENT	DRY DEVELOPMENT
LONG EXTENSION OF PARTLY DEVELOPED POOL			2	OUTPOST OR EXTENSION	EXTENSION (SOMETIMES NEW-POOL DISCOVERY WELL)	DRY EXTENSION
NEW POOL ON STRUCTURE/ENVIRONMENT ALREADY PRODUCTIVE	WITHIN LIMITS OF PROVEN POOL	ABOVE DEEPEST PROVEN POOL	3	SHALLOWER POOL	SHALLOWER POOL DISCOVERY	DRY SHALLOWER POOL
		BELOW DEEPEST PROVEN POOL	4	DEEPER POOL	DEEPER POOL DISCOVERY	DRY DEEPER POOL
	OUTSIDE LIMITS OF PROVEN POOL		5	NEW POOL WILDCAT	NEW POOL DISCOVERY (SOMETIMES EXTENSION WELL)	DRY NEW POOL
NEW FIELD ON STRUCTURE/ENVIRONMENT NEVER BEFORE PRODUCTIVE			6	NEW FIELD WILDCAT	NEW FIELD DISCOVERY	DRY NEW FIELD WILDCAT



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APPENDIX 6:

DERIVATION OF THE MATHEMATICAL MODEL USED TO SIMULATE THE OFFSHORE/ONSHORE EXPLORATION DECISION

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DERIVATION OF THE MATHEMATICAL MODEL USED TO SIMULATE THE OFFSHORE/ONSHORE EXPLORATION DECISION

A. Derivation of the Time-Profile of Production

Production from a reservoir over time is proportional to pressure remaining in the reservoir:

letting $q(t)$ = production in time t
$P(t)$ = remaining reservoir pressure in time t
k_1 = constant of proportionality

$$q(t) = k_1 \cdot P(t) \tag{1}$$

Over time, the remaining reservoir pressure decreases with cumulative production from the reservoir, approximately linearly with cumulative production:

letting $Q(t)$ = cumulative production in time t
k_2 = constant of proportionality

$$P(t) = P_O - k_2 \cdot Q(t) \tag{2}$$

Substitution of (2) into (1) yields:

$$q(t) = k_1 P_0 - k_1 \cdot k_2 \cdot Q(t) \tag{3}$$

Differentiation of (3) with respect to time, t, yields:

$$\frac{dq(t)}{d(t)} = -k_1 \cdot k_2 \frac{dQ(t)}{dt} \tag{4}$$

In any time period t, the change in cumulative production equals production in time period t; therefore:

$$\frac{dq(t)}{dt} = -k_1 \cdot k_2 \, q(t) \tag{5}$$

Equation (5) is the basic differential equation which describes the time profile of production from the reservoir; solving the equation yields:

$$q(t) = q_0 \cdot e^{-k_1 \cdot k_2 t}$$

where:

q_0 = production in the first year (t_1) after reservoir development is completed
$k_1 \cdot k_2$ = decline rate of the reservoir = A

or $$q(t) = q_0 e^{-At} \tag{6}$$

For convenience, it is advantageous to express the equation describing the time profile of production as a function of recoverable reserves in the reservoir, where recoverable reserves equal the cumulative production from the reservoir until well abandonment. From (6):

letting T = time period t when abandonment occurs
R = recoverable reserves

$$R = Q(T) = \int_1^T q_0 e^{-At} dt$$

$$\therefore \quad R = \frac{q_0(1-e^{-AT})}{A} \tag{7}$$

For most wells, the constant term $(1-e^{-AT})$ is approximately equal to 1, because the e^{-AT} term is small; therefore, substituting (7) into (6) yields:

$$q(t) = \frac{R \cdot A \cdot e^{-At}}{1-e^{-AT}} = R \cdot A \cdot e^{-At} \tag{8}$$

B. Derivation of Revenues and Costs of Reservoir Development and Production

Revenues from production from a petroleum reservoir in any time period t equal price per unit output in time t times the quantity produced in time t, or:

letting $P(t)$ = price/unit in time t
$D(t)$ = revenues in time t
r = royalty rate

$$D(t) = P(t) \cdot q(t)(1-r) \tag{9}$$

During a year of petroleum production, costs of production in time t equal cost per unit of production in time t times the quantity produced in time t, or:

letting $O(t)$ = lifting and gathering costs per unit in time t
$C(t)$ = costs in time t

$$C(t) = O(t) \cdot q(t) \tag{10}$$

Before production can occur, however, costs to explore and develop the reservoir are incurred. To simplify, we assume that all exploration and development occurs before the first production year (t_1). * The magnitude of these is related to the number of wells required to explore and develop the reservoir and to the average cost per well, including equipping costs.

*We also assume the exploration and development occur instantaneously.

letting n = number of wells
W = average cost per well

$$C_O = n \cdot W \tag{11}$$

As is the case with the time profile of production, q(t), it is convenient to express the initial costs, C_0, in terms of recoverable reserves (R) and the decline rate (A). First, for simplicity, we assume that initial production (q_0) in time period t_1 is linearly related to the number of exploratory and development wells drilled, or

$$q_0 = k_3 n \tag{12}$$

where:

k_3 = constant of proportionality

Then, from (7), remembering that $(1-e^{-AT}) \approx 1$,

$$k_3 \cdot n = R \cdot A \tag{13}$$

and for later use $A/k_3 = n/R$, the number of wells drilled per barrel of reserves.

Substituting into (11) yields:

$$C_O = \frac{R \cdot A \cdot W}{k_3} \tag{14}$$

C. Derivation of the After Tax Cash Flow Time Profile from the Reservoir

Generally, in any time period t, the after tax cash flow from a reservoir is expressed by:

$$F(t) = D(t) - C(t) - g(t) \tag{15}$$

where:

g(t) = taxes paid in time period t

Above, we derived the revenue (D)- and cost (C)-related cash flow relations. Like costs (C), taxes (g) are different in the exploratory time period (t_O) and production periods (t_1, t_2 .... t_T). In any year, taxes paid are equal to taxable income times the corporate tax rate, after special tax provisions provided for petroleum resources are considered.

In the time period before production, taxes amount to (considering equation (13)):

$$g_0 = -n \cdot W \cdot x \cdot c \tag{16}$$

where:

x = the percent of exploration and development costs expensed immediately
c = corporate tax rate

Substituting into equation (15); and using equation (14):

$$F_O = D_O - C_O - q_O$$
$$= D_O - \frac{R \cdot A \cdot W}{k_3} + n \cdot W \cdot xc$$

Further substituting equation (13) yields:

$$= D_O - \frac{R \cdot A \cdot W}{k_3} + \frac{R \cdot A}{k_3} \cdot W \cdot x \cdot c, \text{ where } D_O = \emptyset$$

$$F_O = -(1-xc)\frac{R \cdot A \cdot W}{k_3} \qquad (17)$$

In all production time periods, taxes are further reduced by application of percentage depletion. Therefore taxes amount to:

$$g_{(t)} = c\left[P(t) \cdot q(t) \cdot (1-r) - O(t) \cdot q(t) - d \cdot P(t) \cdot (1-r) \cdot q(t)\right]$$
$$t>0$$

where:

d = the rate of percentage depletion

Substituting into equation (15) yields:

$$F(t) = D(t) - C(t) - g(t)$$
$$= P(t)q(t)(1-r) - O(t)q(t) - c\left[P(t) \cdot q(t)(1-r) - O(t)q(t) - d \cdot P(t) \cdot q(t) \cdot (1-r)\right]$$

Solving yields:

$$F(t) - P(t)q(t)(1-r) - c \cdot P(t) \cdot q(t) \cdot (1-r) + c \cdot d \cdot P(t) \cdot q(t) \cdot (1-r) - O(t)q(t) + c \cdot q(t) \cdot O(t)$$

$$= P(t)q(t)(1-r)\left[1-c+c \cdot d\right] - q(t)O(t)\left[1-c\right] \qquad (18)$$

D. Derivation of the Expected Present Value of a Petroleum Reservoir.

The decision to bid on an offshore tract for purposes of exploration depends on its expected present value. Assuming a 100 percent chance of success, the present value (PV) is given by:

$$PV = \int_O^T \left[D(t) - C(t) - g(t)\right] e^{-It} \, dt \qquad (19)$$

$$\int_O^T F(t) e^{-It}$$

where:

T = time to abandonment
I = after tax cost of capital

A bidding decision, however, cannot assume a 100 percent success rate. Consequently, the expected present value (EPV) equals the present value times the probability of success less losses than can be anticipated if the operation is not successful times the probability of failure. The losses of failure are given by:

$$L = (1-cf)H \tag{20}$$

where:

L = losses, after tax effects
f = fraction of dry hole costs which can be expensed immediately for tax purposes
H = dry hole costs

Therefore the expected present value of a tract, given a probability of success (Y), is given by:

$$EPV = Y\int_1^T F(t)e^{-It}dt + Y \cdot F_O - L$$

Substituting equations (17), (18) and (20) yields:

$$= Y\int_1^T \left[1-c+c\cdot d\right] P(t)q(t)(1-r)\cdot e^{-It}dt - Y\int_1^T \left[1-c\right] q(t)\cdot O(t)e^{-It}dt + Y\left[-(1-xc)\frac{R\cdot A\cdot W}{k_3}\right] - (1-Y)(1-cf)H$$

Substition equation (8):

$$EPV = Y\int_1^T \left[1-c+cd\right]\left[1-r\right]P(t)\cdot R\cdot A\cdot e^{-At}\cdot e^{-It}dt - Y\int_1^T \left[1-c\right] O(t)\cdot R\cdot A\cdot e^{-At}\cdot e^{-It}dt - Y\left[(1-xc)\frac{R\cdot A\cdot W}{k_3}\right] - (1-Y)(1-cf)H \tag{21}$$

Integrating equation (21) and assuming T is large, so that the $e^{-(A+I)t}$ terms go to zero, yields:

$$EPV = Y\left\{\frac{\left[1-c+cd\right]\left[1-r\right]P\cdot A\cdot R}{A+I}\right\} - Y\left\{\frac{\left[1-c\right]O\cdot A\cdot R}{A+I}\right\} - Y\left\{(1-xc)\frac{R\cdot A\cdot W}{k_3}\right\} - (1-Y)(1-cf)H$$

Therefore:

$$EPV = Y\left\{\left[\frac{(1-c+cd)(1-r)P\cdot A\cdot R}{A+I}\right] - \left[\frac{(1-c)O\cdot A\cdot R}{A+I}\right] - \left[(1-xc)\frac{(R\cdot A\cdot W)}{k_3}\right]\right\} - (1-Y)(1-cf)(H)$$

Remembering from equation (13) that $\frac{A}{k_3} = \frac{n}{R}$, or the number of wells drilled per barrel of reserves and letting:

$B = \frac{A}{k_3} = \frac{n}{R}$ and substituting above yields

$$EPV = Y\left\{\left[\frac{(1-c+cd)(1-r)P\ A\ R}{A+I}\right]-\left[\frac{(1-c)\ O\ A\ R}{A+I}\right]-\left[(1-xc)(R\ B\ W)\right]\right\}-(1-Y)(1-cf)H$$

APPENDIX 7:

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APPENDIX 7

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